Observation

RADIATION PROTECTION PERFORMANCE INDICATORS AT THE NUCLEAR POWER PLANT KRŠKO*

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Nuclear power plant safety performance indicators are developed "by nuclear operating organisations to monitor their own performance and progress, to set their own challenging goals for improvement, and to gain additional perspective on performance relative to that of other plants". In addition, performance indicators are widely used by regulatory authorities although the use is not harmonised. Two basic performance indicators related to good radiation protection practice are collective radiation exposure and volume of low-level radioactive waste.
In 2000, Nuclear Power Plant Krško, a Westinghouse pressurised water reactor with electrical output 700 MW, finished an extensive modernisation including the replacement of both steam generators. While the annual volume of low-level radioactive waste does not show a specific trend related to modernisation, the annual collective dose reached maximum, i.e. 2.60 man Sv, and dropped to 1.13 man Sv in 2001. During the replacement of the steam generators in 2000, the dose associated with this activity was 1.48 man Sv. The annual doses in 2002 and 2003 were 0.53 and 0.80 man Sv, respectively, nearing thus the goal set by the US Institute of Nuclear Power Operators, which is 0.65 man Sv. Therefore, inasmuch as collective dose as the radiation protection performance indicator are concerned, the modernisation of the Krško nuclear power plant was a success.

KEY WORDS: *annual collective dose, low-level radioactive waste, nuclear power operator, occupational dose, outage*

According to the World Association of Nuclear Operators (WANO), nuclear power plant safety performance indicators are developed "by nuclear operating organisations to monitor their own performance and progress, to set their own challenging goals for improvement, and to gain additional perspective on performance relative to that of other plants" (1). In addition, performance indicators are widely used by regulatory authorities, although the use has not yet been harmonised (2). In 2000, Nuclear Power Plant (NPP) Krško (Westinghouse pressurised water reactor, PWR, with electrical output 700 MW) finished an extensive modernisation including the replacement of both steam generators. This article looks into the changes in radiation protection performance indicators after the modernisation and the problems related to their use.

MODERNISATION OF THE NPP KRŠKO

The commercial operation of the NPP Krško started in 1983. The modernisation took place from 1996 to 2000 in order to stabilise long-term plant

*Preliminary report presented at the 6th Symposium of the Croatian Radiation Protection Association with international participation, Stubičke Toplice, Croatia, 18-20 April 2005 operation; increase net electrical output by 6.3 %; reduce annual outage duration to ~30 days; increase availability to 85 % (unit forced outage rate <2 %); and increase annual energy production to ~5TWh.

The modernisation included the replacement of two steam generators, installation of a plant–specific, full-scope simulator at the plant site and In-Core Cooling Monitoring (ICCM). The modernisation was successfully completed and the licensed reactor thermal power was upgraded to 1996 MWt. Both steam generators were replaced in 2000 during the annual outage which lasted for 62 days.

RADIATION PROTECTION PERFORMANCE INDICATORS

The performance indicators which are widely used in NPPs over the last years and which are promoted by WANO are unit capability factor, unplanned capability loss factor, unplanned automatic scrams per 7000 hours critical, thermal performance, collective radiation exposure, volume of low-level solid radioactive waste, industrial safety accident rate, safety system performance (high pressure safety injection, auxiliary feedwater, emergency AC power), fuel reliability, and chemistry index.

In addition, other performance indicators are often used by a specific NPP such as time availability factor, load factor, and the duration of annual outage. In addition, self assessment procedures which were developed in the last years involve more and more internal indicators in order to follow the evaluation of the safety in the plant.

These performance indicators are not used just by the NPPs, but also by regulatory authorities. The indicators have not yet been harmonised, and are usually the result of an agreement between the NPP and the regulatory authority. Neither the role of performance indicators in legislation is harmonised in all countries.

The basic performance indicators which are related to radiation safety are collective radiation exposure, volume of low-level radioactive waste, fuel reliability, and chemistry index.

Among them, collective radiation exposure and the volume of low-level radioactive waste are obviously related to good radiation protection practice. Other performance indicators mentioned are less obviously connected to radiation protection. The fuel reliability indicator (FRI) monitors progress in achieving and maintaining high fuel integrity and is defined as a corrected steady-state primary coolant ^{131}I activity. The chemistry index measures the efficiency of the control of chemical impurities in the secondary coolant water PWRs.

Collective radiation exposure

Collective radiation exposure measures the total radiation exposure of plant personnel and also the effectiveness of radiological protection programmes. Occupational dose is measured either using a film or a thermoluminescence (TL) dosimeter. In addition to film or TL dosimeters, workers at nuclear plants wear operational dosimeters in order to monitor occupational doses related to specific jobs. The operational dosimeter alarms a worker with a sound or light if the dose is above the predefined value. As the doses measured by operational dosimeters are highly uncertain, NPPs usually do not use the readings of operational dosimeters to monitor occupational doses. These readings are taken into account only when the readings from TL dosimeters or film badges are not available and this is very rare, mainly due to very high safety standards and strict regulatory control of NPPs.

The annual collective dose is the sum of all occupational doses related to all jobs in one year. The workers at NPPs usually do not perform just one job, and their annual exposure is related to different jobs, i.e. maintenance and supervision during normal operation of a plant, maintenance and supervision during refuelling, processing of radioactive waste, and so on. Film or TL dosimeter readings are evaluated every month and include all occupational exposure-related activities performed in a specified period. As a rule, the collective dose related to waste processing accounts for a few percent of the total collective dose, while the collective dose related to refuelling usually accounts for about 80 % of the total annual collective dose. Figure 1 shows annual collective radiation exposure from 1996 to 2003 in the NPP Krško, based on TL dosimeter readings.

Before both steam generators were replaced, there was an increase in the annual collective dose, partly due to an intervention on the steam generators and partly due to final-stage modernisation operations associated with higher occupational doses. After modernisation the annual collective dose has dropped substantially, and is comparable to the annual

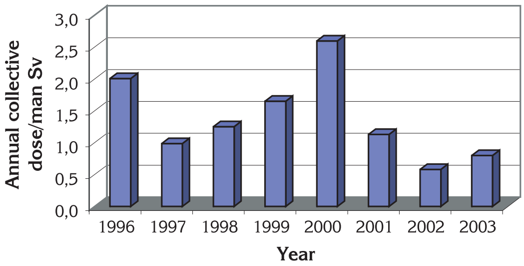

Figure 1 *Annual collective radiation exposure from 1996 to 2003*

exposures reported by other PWRs (3). The goal of the Institute of Nuclear Power Operations (INPO) in the USA, which promotes "the highest levels of safety and reliability" and "excellence in the operation of nuclear electric generating plants" is 650 man mSv (=0.65 man Sv) for the year 2005 (4). In 2000, the annual collective dose was 2.60 man Sv due to the steam generator replacement, which accounted for 1.48 man Sv.

Volume of low-level radioactive waste

The volume of low-level radioactive solid waste produced shows a dropping trend, which will decrease storage, transportation and final disposal needs. Low-level radioactive solid waste is defined as all waste that is not spent fuel; it includes only the waste which was processed, and it is in its final form. The annual production of low-level radioactive solid waste from 1996 to 2003 is given in Figure 2.

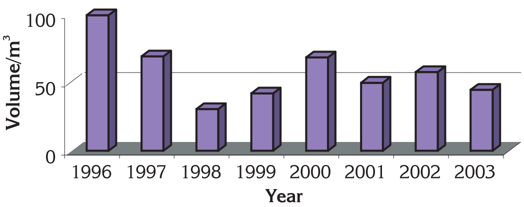

Figure 2 *Annual production of low-level radioactive solid waste from 1996 to 2003*

The production of low-level radioactive solid waste already has decreased since 1996 due to improved radioactive waste management, which is supported by new procedures, including the In Drum Drying System and a very stringent radioactive management system (5).

CONCLUSION

It takes a few performance indicators to recognise a good radiation protection practice in an NPP. The collective dose and the volume of low-level radioactive waste are the most obvious performance indicators. After the modernisation of the NPP Krško the annual collective dose has decreased substantially and has approached the INPO goal for the year 2005. A drop in the production of low-level radioactive solid waste is the result of a very stringent programme for radioactive waste management control.

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Povzetek

KAZALCI UVELJAVLJANJA VARSTVA PRED SEVANJEM V JEDRSKI ELEKTRARNI KRŠKO

Varnostne kazalce jedrskih elektrarn, ki so jih razvili operaterji jedrskih elektrarn z namenom, da spremljajo lasten napredek in razvoj, lahko uspešno uporabijo tudi regulatorni organi za jedrsko energijo, ki želе oceniti nivo varstva pred sevanji v elektrarni. Osnova varnostna kazalca, ki sta povezana z uspešnim uveljavljanjem varstva pred sevanji, sta kolektivna doza ter volumen nizko radioaktivnih odpadkov. Analiza varstva pred sevanji pred in po modernizaciji jedrske elektrarne Krško, ki je 700 MW tlačnovodna elektrarna proizvajalca Westinghouse, lahko temelji na obeh omenjenih kazalcih. Modernizacija je zajemala tudi zamenjavo obeh uparjalnikov v letu 2000.
Analiza je pokazala, da spremembe v letnem volumnu nizko radiaktivnih odpadkov niso bile povezane z modernizacijo elektrarne. Letna kolektivna doza pa je dosegla v letu 2000 maksimalno vrednost in sicer je znašala 2,60 človek Sv, v letu 2001 pa le še 1,13 človek Sv. Letne kolektivne doze, ki so v času pred modernizacijo iz leta v leto naraščale in so tik pred modernizacijo v letu 2000 dosegle vrednost 2,6 človek Sv, so v letih 2002 in 2003 padle na 0,53 oziroma 0,80 človek Sv. S tem so se približale cilju letne kolektivne doze 0,65 človek Sv, ki si ga je zastavil Institute of Nuclear Power Operation v ZDA. Glede na te rezultate je bila modernizacija elektrarne z vidika varstva pred sevanji uspešna.

KLJUČNE BESEDE: *doza delavca, letna kolektivna doza, nuklearni operater, radioaktivni odpadki, remont*

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